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Petri Nets Simulator With Individual Tokens

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User's manual

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1. Foreword

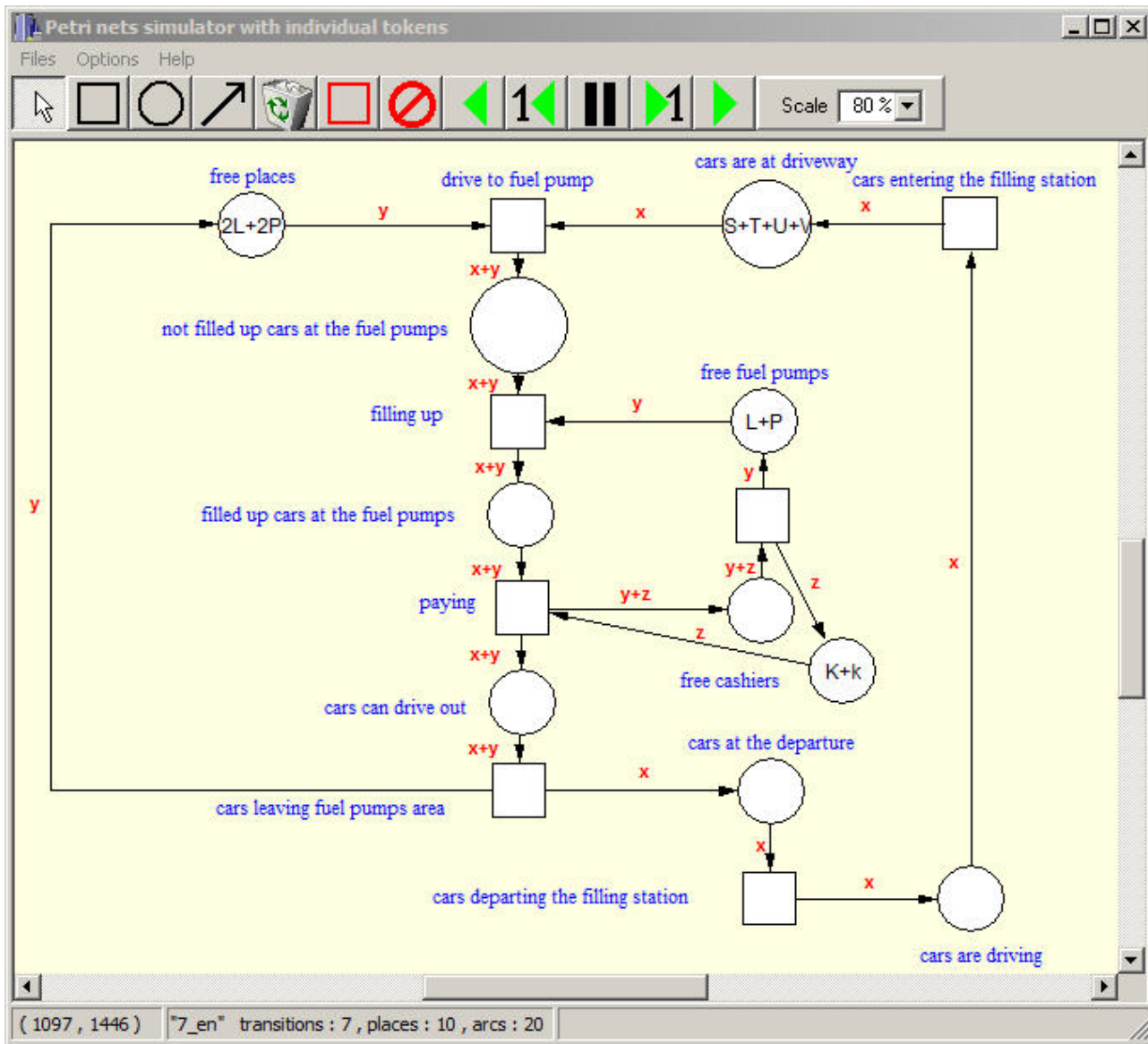
Application allows you to create, analyse and simulate the following types of Petri nets:

PT nets, nets with individual tokens and constant arc labels and nets with individual tokens and variable arc labels.

Program works with Microsoft Windows XP, Vista, 7, 8.

Program has an intuitive graphical user interface.

2. Main window description



Main program window contains menu bar, tool bar, drawing area and status bar divided into three fields.

Menu contains the followins submenus: **Files**, **Options** i **Help**.

Submenu **Files** contains the following items:

New - removes existing net from the drawing area.

Open - reads the net from files.

Save - writes the net to files.

Merge nets – reads the net from files and adds it to the current net.

Save selected fragment – writes selected Petri net fragment to files.

Eksport drawing - creates BMP file containing net drawing in the selected scale.

Print net - prints net to the selected printer.

Printer settings - selects printer, its resolution and sheet size.

Exit - shuts the program down.

Submenu **Options** contains the following items:

Renumber objects - renumbers places and transitions starting from 1

Analyze net's properties - starts Petri Nets Analyzer.

Program settings - editing the graphical properties of the net and configuration of the simulation parameters.

Language - changes the language between english and polish, and then program restarts).

Submenu **Help** contains items:

User's manual - opens the html browser and shows this manual.

About - shows information about the program and its author.

Drawing area allows you to view and edit Petri Nets.

It is equipped with sliders, you can use them to move the field of view over larger drawing area.

The mouse wheel provides a convenient way to move the field of view. To move the field of view horizontally, rotate the roller while holding the right mouse button.

Roller is disabled while moving and sizing all objects.

When you move an object to the edge of the drawing area, the field of view scrolls automatically.

Note: The automatic movement of the field of view is not working during the simulation of the Petri net.

(1151, 1953) "7_en" transitions : 7 , places : 10 , arcs : 20 transition no. 2 "filling up"

Status bar allows program to display various informations.

The left field displays information about the position of the cursor on the drawing in format:

(coordinate X, coordinate Y), the left top corner of the drawing has the coordinates (0 , 0)

The middle field displays the file name of the Petri Net and the number of transitions, places and arcs in the Petri net.

Right field displays the serial number and the name of the object or fired transition.

If you select more than one object, this field displays number of selected places and transitions.

During the simulation of the Petri net the right field displays information about the recently fired transitions or information that it's impossible to fire any transition.



The toolbar contains the following icons:



Point objects - allows you to select objects, change its properties, move and change its shape and size.

When you click on the object the handles will appear, that allow you to change the object size and shape, and in the right field of the status bar information about the object will appear.

To move an object, position the mouse pointer inside this object, then drag it to a new location.

When you move an object outside the field of view, it will automatically scroll in the direction of the mouse cursor.

When you reach the desired position on the drawing area, drop the object.

These tips are also valid for the selected group of objects .

To select multiple objects, you must surround them with the selection frame, or click on them in succession while holding down the Shift key. The selection frame will appear, when you start dragging mouse cursor at empty position on the drawing. By holding the Shift key while calling the selection frame for the group of objects, you can select the new objects while not deselecting the already selected. Selected objects can be saved to a new Petri Net by using the menu option "Save Selected".

Hold down the Ctrl key while dragging the selected objects to copy them to a new position on the drawing.

To edit an object's properties, double-click on this object or its description -

- the object properties window will appear.


To delete an object, select it and press Delete key.


To bend the arc, select it and drag a handle.


To straighten out the arc, select it and press the spacebar.





Add transitions - after clicking at the desired location on the drawing a new transition will appear. If you choose an appropriate option of the "Program Settings" dialog window (Editor page), the "Edit Transition" dialog window will appear.


 **Add places** - after clicking at the desired location on the drawing a new place will appear. If you choose an appropriate option of the "Program Settings" dialog window (Editor page), the "Edit Place" dialog window will appear.


 **Connect places and transitions by arcs** - move the mouse cursor on the first object (transition or place), then drag the mouse cursor on the second object (respectively: place or transition). If the second object is outside the edge of the screen, mouse hover on the edge while holding the left button to scroll the field of view. When you move the mouse cursor to another object and release the left mouse button, the objects will be connected by an arc. If you choose an appropriate option of the "Program Settings" dialog window (Editor page), the "Edit Arc" dialog window will appear. If this option is not selected, the new arc will be labeled with one black token. Double-click on the new arc to edit its properties. To remove the newly created arc press the Delete key.


 **Delete objects** - select the object, and then click the on-screen button or press Delete key to remove the object from the drawing. If you delete a place or transition, it will also remove all arcs connected to it.


 **Block transition** [key B] - select the transition and press this screen button to prevent firing of the transition. Select a blocked transition and press this screen button to unlock the transition.


 **Allow / disallow changing assignments of tokens to the variables** [key. A] changes the strength (definition) of the transition firing - when the transition has a red frame, it is possible to change the assignments of tokens to the variables labelling the arcs during the transition firing. If the transition has a black frame, is not possible to change the once given assignments of tokens to the variables labelling the arcs.

 **Start the simulation backwards** [key W] – Press this button to run the Petri Net backwards. The simulation speed can be changed in the "Program Settings" dialog window. In the simulation mode you can not add or delete objects, and the automatic scrolling of the field of view while dragging objects is disabled.

 **Revert the simulation by one step** [key C] - by pressing this button, one transition will be fired backward. Transitions selected by the user have higher priority than others. In this way you can force firing the selected transition backward, just click on it and then press C. Blocked transitions can not be fired.

 **Stop the simulation** [key Z] – Press this button if you want to edit the Petri Net or if you want to change direction of the simulation (this requires its prior stop).

 **Start simulation** [key S] - Press this button to run the Petri Net. The simulation speed can be changed in the "Program Settings" dialog window. In the simulation mode you can not add or delete objects, and the automatic scrolling of the field of view while dragging objects is disabled.

 **Do one step of the simulation** [key Enter] - by pressing this button, one transition will be fired forward. Transitions selected by the user have higher priority than others. In this way you can force firing the selected transition forward, just click on it and then press Enter.

Blocked transitions can not be fired.

Scale 100 % ▼

Scale drawing of the Petri Net - choose a scale from 10% to 200 %. The scale can be selected from a list or entered from the keyboard. Using the [+] and [-] on the numeric keypad, you can smoothly change the drawing scale (zoom effect).

3. Edit place dialog window

In this window you can edit properties of the place.

You can enter the contents of the place by specifying number of tokens in each color following by name of this color, separating further elements of the multiset by character + . Black token is represented by the color name @. Color names may have length of one or many characters.

Entry field "Assignments" allows for tokens of any color to determine the meaning of this color, the variable to which tokens of the specified color will be assigned during firing of the transition located in the output (postset) of the edited place. Thus, an individual token is a pair (constant, variable), where the constant determines color of the token and variable is a label of the arc defining its meaning. This prevents changing the meaning of the color tokens during simulation of the Petri Net.

If you don't specify the color assignment of a token, program will choose the assignment of this color to the output arc's variable when the firing transition retrieves the token(s). Then it will write this assignment together with the cardinality of this color tokens in all places from the output (postset) of this transition.

Entry field "Capacity" determines the maximum capacity of the edited place; 0 means unlimited capacity.

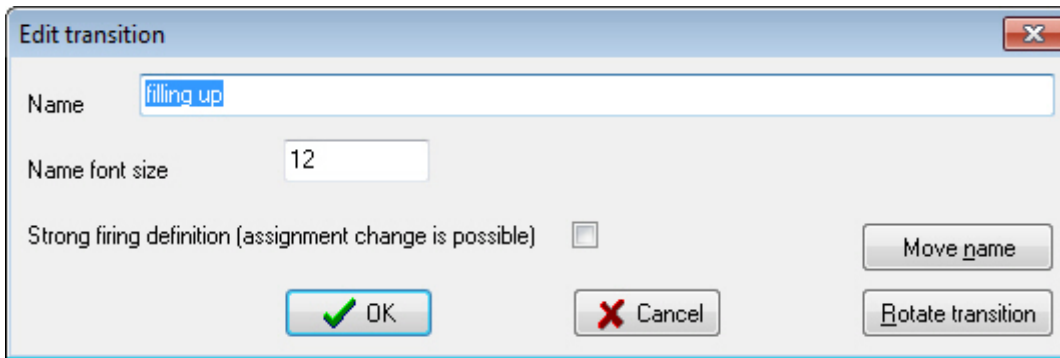
After pressing the screen button "Move name" dialog window closes and at the mouse cursor appears a rectangular frame with its size related to the name.

Move the frame to the desired location and press the left mouse button to relocate the name.

When you move the name, program automatically advances the field of view. To do this, place the cursor near the edge of the drawing area.

When you move the name, mouse wheel does not work - please use the automatic scrolling.

4. Edit transition dialog window



In this window you can edit properties of the transition.

Checkbox "Strong firing definition" allows you to change force (definition) of the firing - if it is checked then during transition firing a change of the once given assignment of colored tokens to the variables may occur.

When the checkbox is not checked (weak firing definition), the once given assignment can not be changed. The strength with which the transition can fire is indicated on the drawing by color of the transition – black for the weak definition of the firing, and red for the strong definition of the firing.

After pressing the screen button "Move name" dialog window closes and at the mouse cursor appears a rectangular frame with its size related to the name.

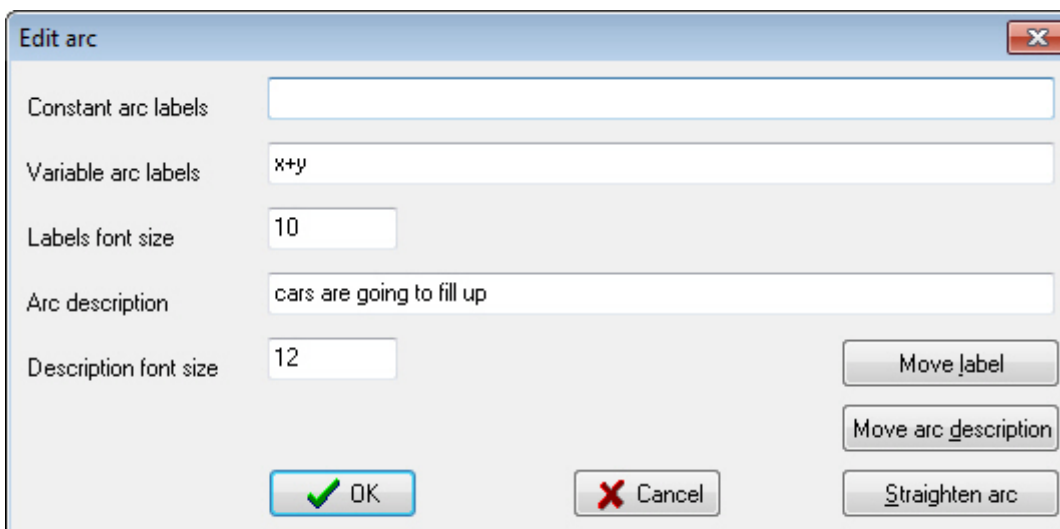
Move the frame to the desired location and press the left mouse button to relocate the name.

When you move the name, program automatically advances the field of view. To do this, place the cursor near the edge of the drawing area.

When you move the name, mouse wheel does not work - please use the automatic scrolling.

After pressing the screen button "Rotate transition", it rotates by 90 ° relative to its center and the appropriate displacement of the transition name will occur, if necessary.

5. Edit arc dialog window



In this window you can edit properties of the arc.

You can edit constant labels by entering cardinality of tokens and color names, separating the next item by a + symbol.

Token names must begin with a letter. The exception is a black marker, represented by the @ character.

You can edit variable labels by entering cardinality of tokens and variable names, separating the next item by a + symbol.

Variable names must begin with a letter.

After pressing the screen button "Move label" or "Move arc description" dialog window closes and at the mouse cursor appears a rectangular frame with its size related to the caption.

Move the frame to the desired location and press the left mouse button to relocate the caption.

When you move the caption, program automatically advances the field of view. To do this, place the cursor near the edge of the drawing area.

When you move the caption, mouse wheel does not work - please use the automatic scrolling.

Screen button "Straighten arc" works like the space bar - straightens the arc polyline.

6. Edit settings dialog window

The settings window contains six pages, which can be changed by clicking on the tabs: "Editor", "Simulator", "Analyzer", "Colors", "Fonts", "Descriptions".

Screen button "Save as default" allows you to set the current settings as the default settings, When you restart the program, the settings will be the same as when you press the button "Save as default".

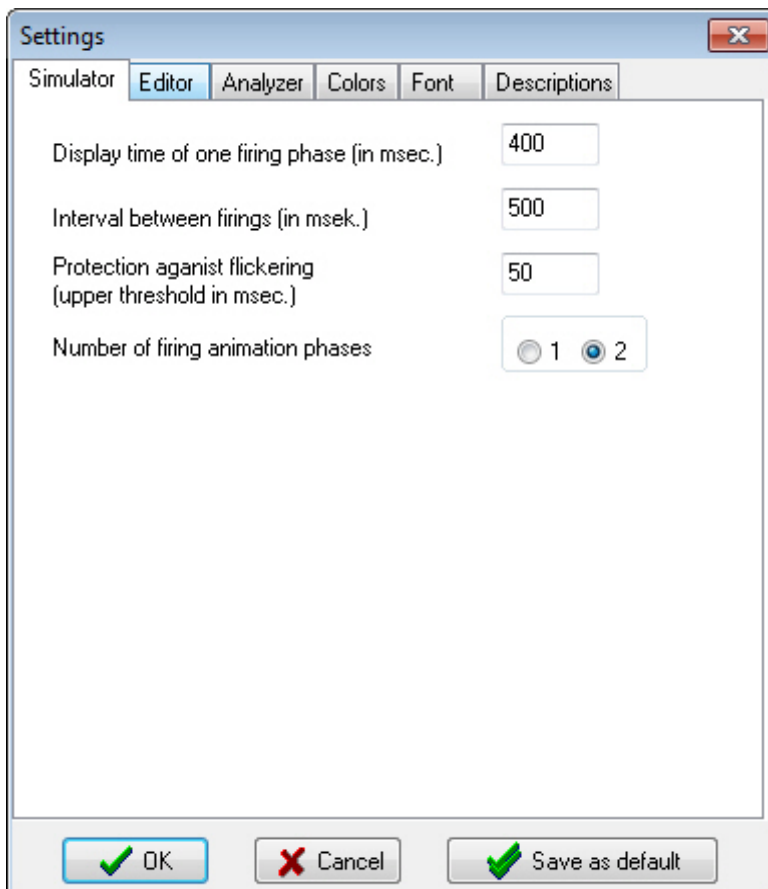
Page "Simulator" defines the behavior of the Petri Nets Simulator.

Firing of transitions can be visualized in one or two phases:

- if there are two phases, then places from an input (preset) of the firing transition are highlighted first, and then the places from an output (postset) of the firing transition are highlighted.

When the firing is visualized in a single phase, the places from preset and postset of a firing transition are highlighted at the same time (in different colors).

Protection against flickering of places shuts down highlighting of places from the preset and postset of firing transition, if the display time of one firing phase is less than or equal to the entered value.



Page "Editor" allows you to configure the appearance of the Petri Net drawing.

Entry fields "Arrowhead length", "Arrowhead thickness", "Arc thickness" refer to all of arcs in the drawing. I advise to configure large arrowheads because they are more visible and less prone to distortions caused by

scaling of the drawing.

Entry fields "Transition width", "Transition height", "Place radius" refer to the newly created objects, and not already created.

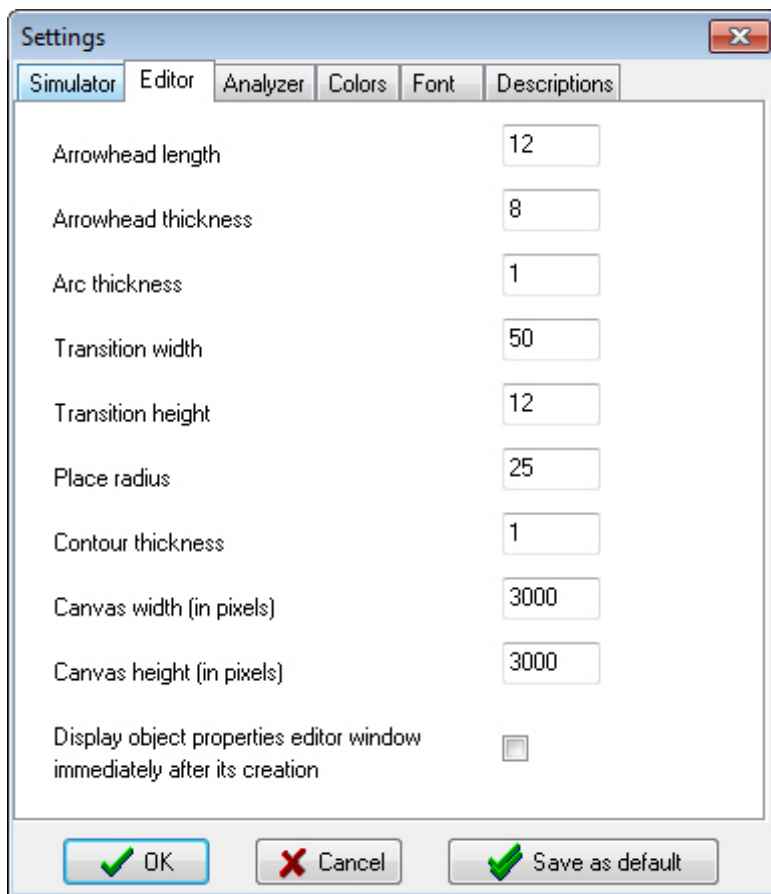
Entry field "Contour thickness" refers to all places and transition on the drawing.

The width and height of the canvas in pixels must be within the range 1000-16000 pixels.

Before reducing the size of the canvas, make sure that Petri Net drawing will fit on the reduced canvas (or part of it will be unavailable for editing).

Control "Display object properties editor window immediately after its creation," enables or disables this option.

This option should be disabled when editing a P/T Petri Net, and enabled when editing a colored Petri Net due to their greater complexity.



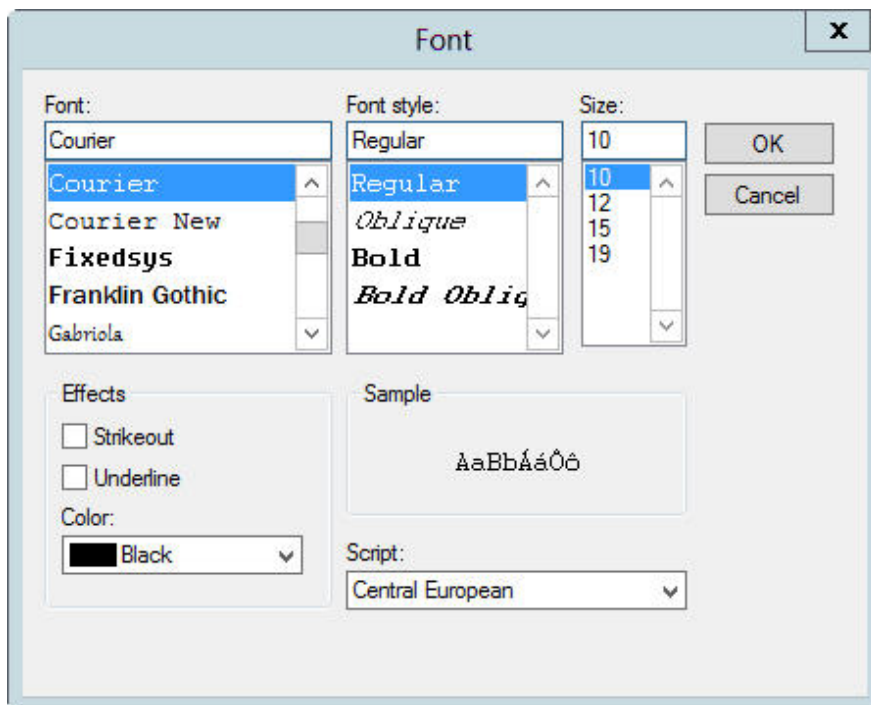
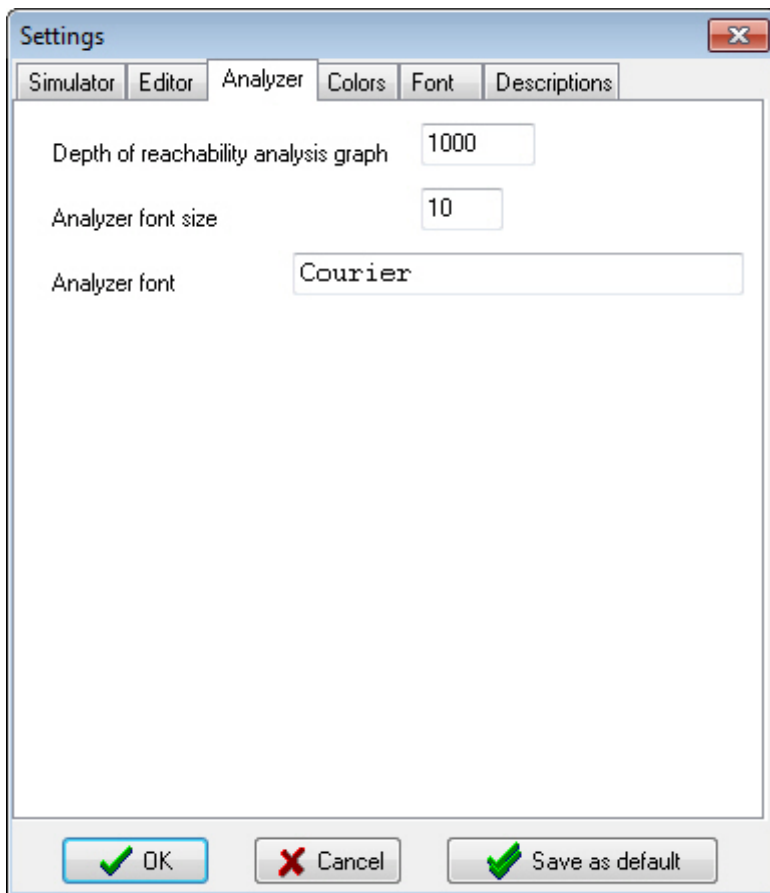
On the "Analyzer" page you can edit the maximum path length of the reachability graph in the "Depth of reachability analysis graph" field. Too low value may prevent the analysis of Petri net liveness, and too large value could lead to excessively long analysis time if the Petri net is not limited and to creating too large file with the reachability graph, which in turn may not fit in computer memory.

On this page you can also select a font to write information in the Petri nets analyzer. Select a font with the same width of all characters to make tables and properties of Petri nets readable.

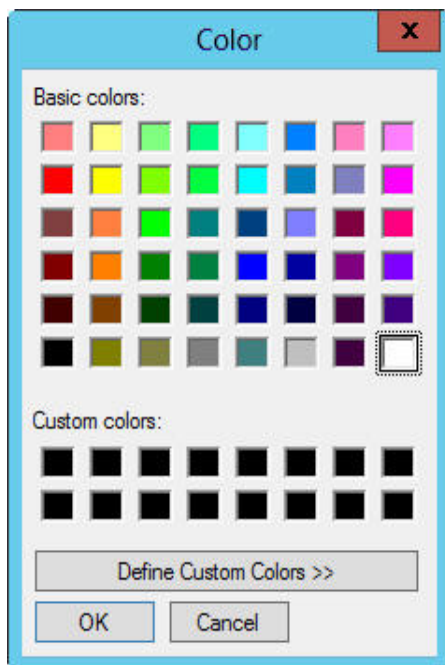
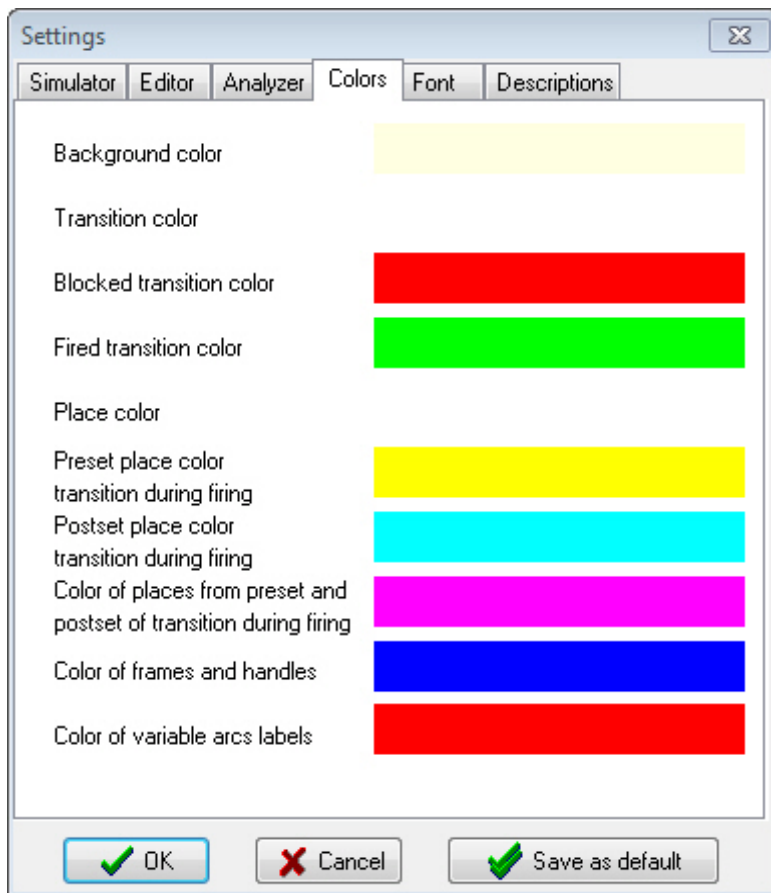
To change the font, click on the white box with the name of the font.

You will see the following font selection window.

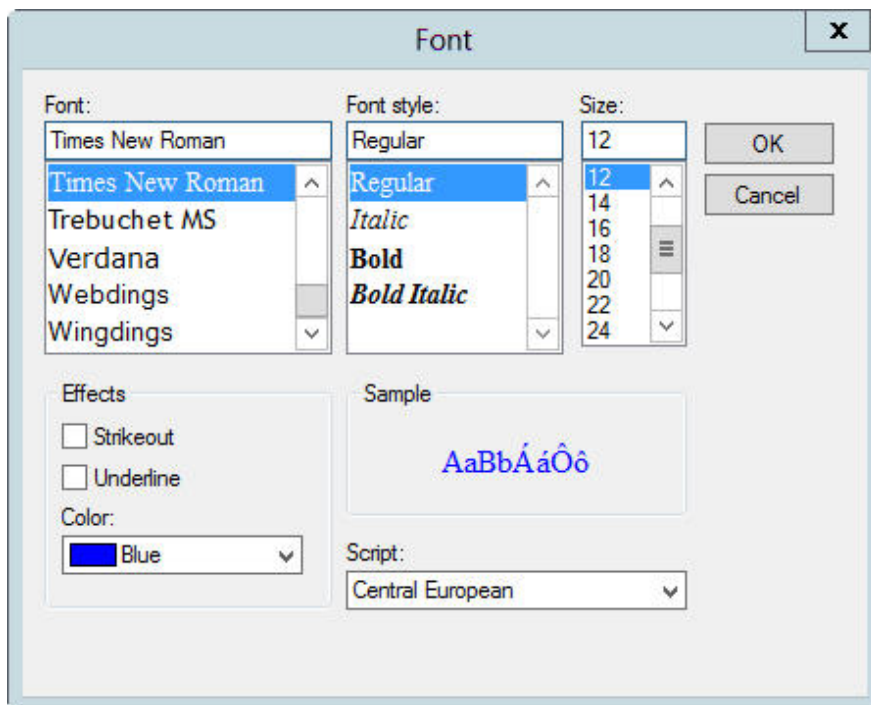
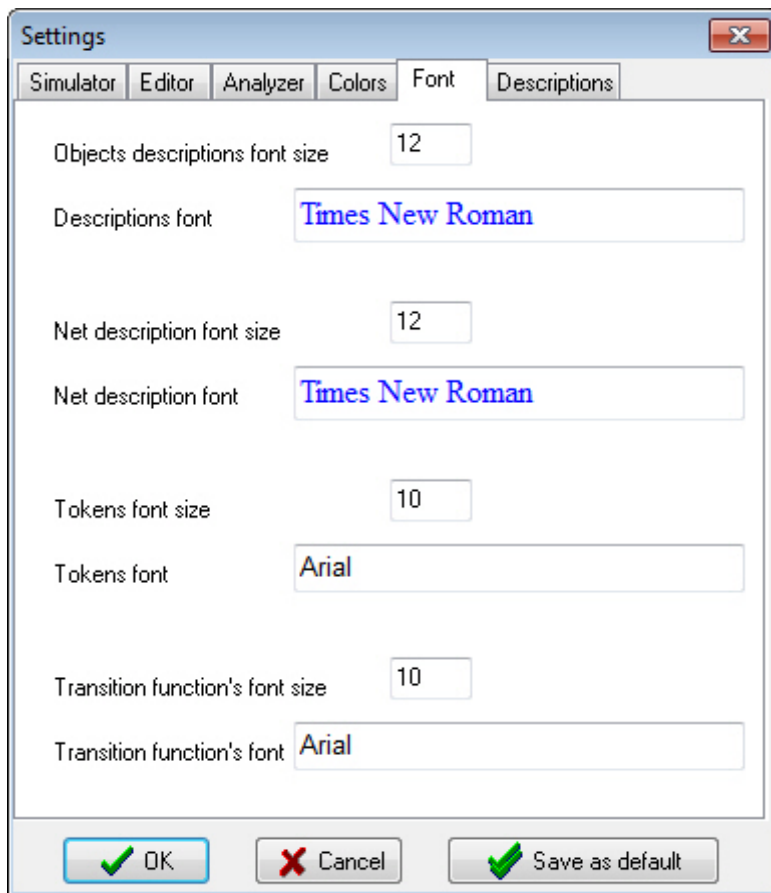
After selecting the font, its size and color, click OK.



Page "Colors" allows you to define colors of specific screen objects.
 To change the color of an object, click on the color bar next to the description of the object.
 You will see the following color selection window.
 After selecting a new color for the object, click OK.



Page Fonts allows you to change the size and typeface of fonts shown on the drawing of the Petri net. To change the font, click on the white box with the name of the font. You will see the following font selection window. After selecting the font, its size and color, click OK.



Page Descriptions allows you to describe the Petri net and enter text describing the maximum capacity of places.

After describing the Petri net, the input can be placed in the desired location on the drawing by pressing the T key.

Description of the Petri net will then be placed on the drawing as indicated by the mouse cursor. You can also enter the coordinates of the Petri net description from the keyboard.

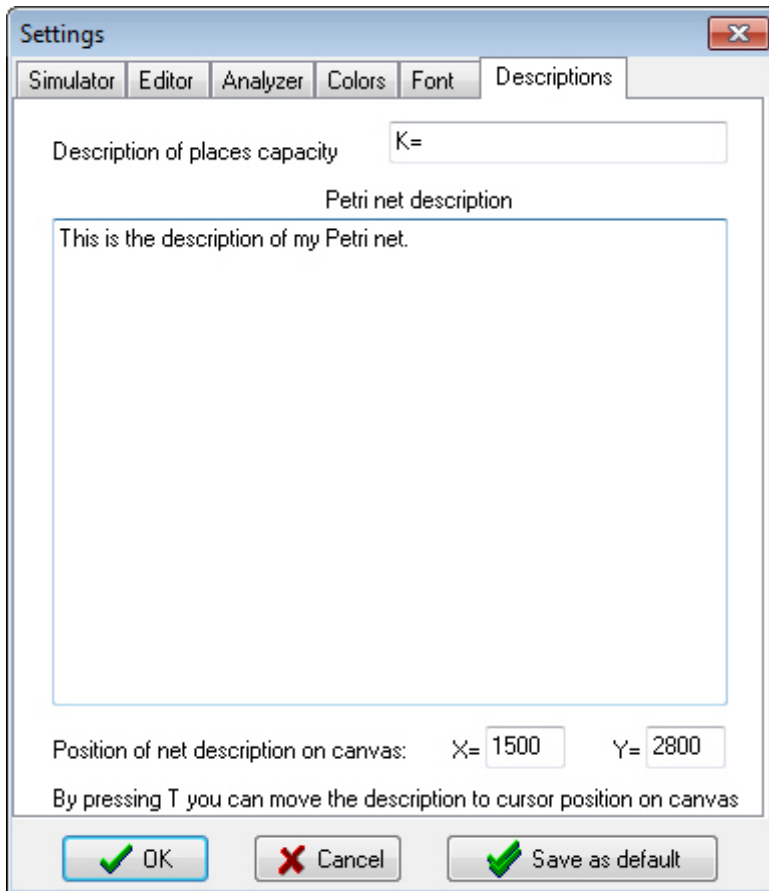
To edit already present description of the Petri net, double click on it.

- Then the following dialog window will appear.

Description of the Petri net can be dragged around the screen like places and transitions - using the "drag and drop".

Note: Before clicking the screen button "Save as default" you may wish to clear the description of the Petri net in order to avoid describing each of the newly created Petri nets with the description of the current Petri net.

Of course you can also use this mechanism to do the opposite - for example, to sign any newly created Petri net with your name or the name of the institution.



7. Petri nets analyzer

Petri nets analyzer is based on the program INA.

INA was modified to allow it to work in a batch mode and to cooperate with program PETRINET.

Therefore, do not substitute it by a different version of the file INAWIN32.EXE.

INAWIN32.EXE file must be in the same directory as the file PETRINET.EXE to allow its execution by the program PETRINET.

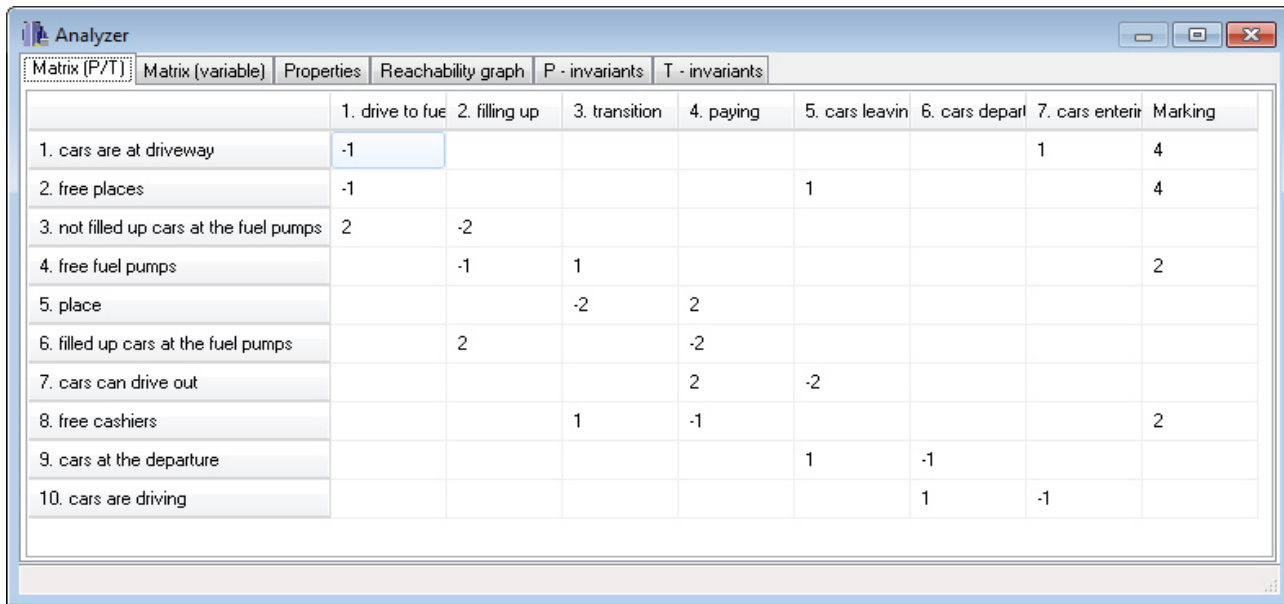
To launch the analyzer after the creation of Petri net, select the analyzer option from the menu.

Analyzer display window contains 5, 6 or 7 pages - depending on the type of the Petri net.

The first page contains a matrix representation of P/T Petri net, that is based on Petri net with individual tokens.

On the basis of matrix representation of the P/T Petri net, program creates files with the PNT and MAR extensions, which are processed by the analyzer INAWIN32.

Unfortunately, the INA can not analyze the network with color individual tokens, and therefore during this conversion occurs loss of some properties of colored Petri net.

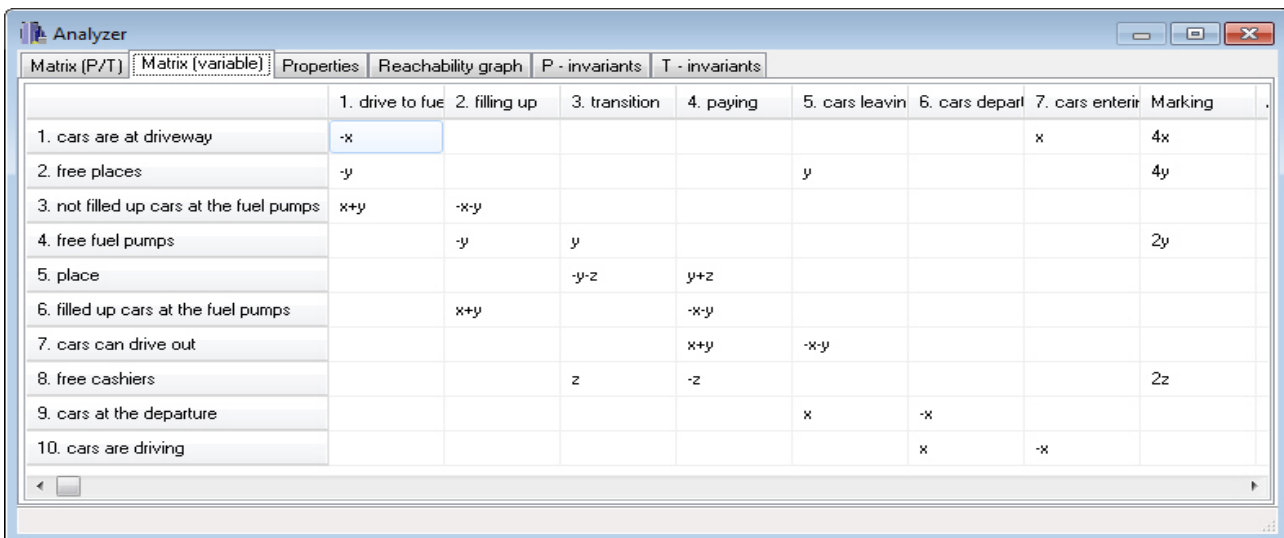


The Analyzer window displays the Matrix (P/T) tab. The table shows the relationship between 10 places and 7 transitions. The places are listed on the left, and the transitions are listed at the top. The marking is shown on the right.

	1. drive to fuel	2. filling up	3. transition	4. paying	5. cars leavin	6. cars depart	7. cars enterir	Marking
1. cars are at driveway	-1						1	4
2. free places	-1				1			4
3. not filled up cars at the fuel pumps	2	-2						
4. free fuel pumps		-1	1					2
5. place			-2	2				
6. filled up cars at the fuel pumps		2		-2				
7. cars can drive out				2	-2			
8. free cashiers			1	-1				2
9. cars at the departure					1	-1		
10. cars are driving						1	-1	

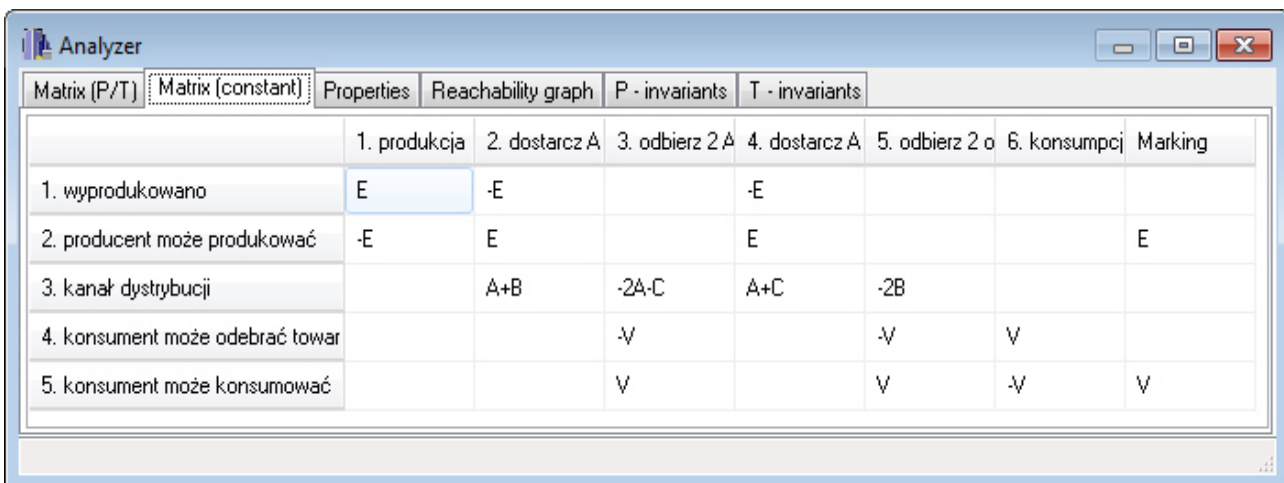
The second page contains a matrix representation of the colored Petri net with individual tokens and variable arcs labels.

It can help you locate properties of colored Petri net that are lost during conversion to the P / T Petri net.



The Analyzer window displays the Matrix (variable) tab. The table shows the relationship between 10 places and 7 transitions using variables x, y, and z. The marking is shown on the right.

	1. drive to fuel	2. filling up	3. transition	4. paying	5. cars leavin	6. cars depart	7. cars enterir	Marking
1. cars are at driveway	-x						x	4x
2. free places	-y				y			4y
3. not filled up cars at the fuel pumps	x+y	-x-y						
4. free fuel pumps		-y	y					2y
5. place			-y-z	y+z				
6. filled up cars at the fuel pumps		x+y		-x-y				
7. cars can drive out				x+y	-x-y			
8. free cashiers			z	-z				2z
9. cars at the departure					x	-x		
10. cars are driving						x	-x	



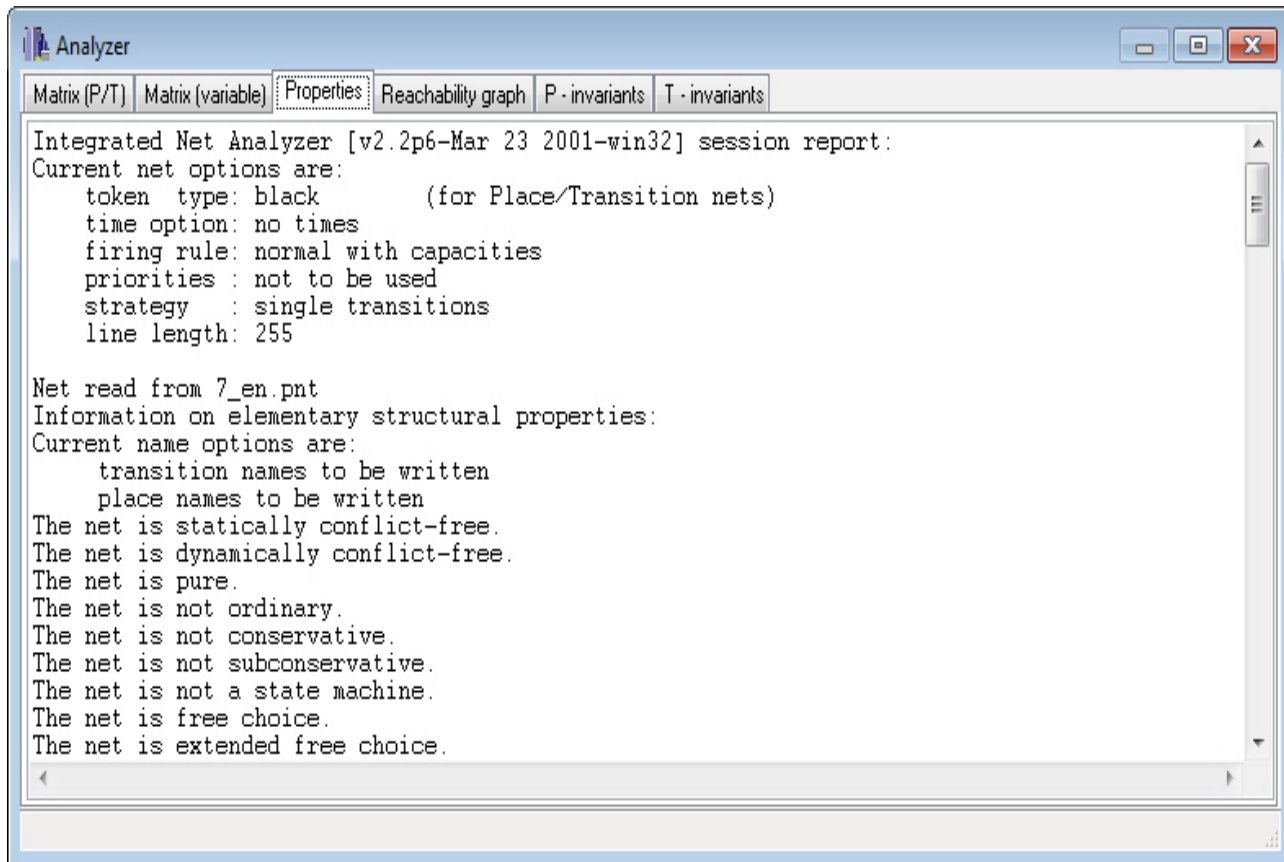
The Analyzer window displays the Matrix (constant) tab. The table shows the relationship between 5 places and 6 transitions using constant values E, A, B, C, V, and -2A. The marking is shown on the right.

	1. produkcja	2. dostarcz A	3. odbierz 2 A	4. dostarcz A	5. odbierz 2 o	6. konsumpcji	Marking
1. wyprodukowano	E	-E		-E			
2. producent może produkować	-E	E		E			E
3. kanał dystrybucji		A+B	-2A-C	A+C	-2B		
4. konsument może odebrać towar			-V		-V	V	
5. konsument może konsumować			V		V	-V	V

The network may also contain individual tokens and constant arcs labels instead of variable arcs labels.

The network may also contain both types of labelled arcs - but this is not recommended because of the possible assignments of tokens that should move through the arcs with constant labels to the arcs with variable labels as a result of the substitution mechanism.

On the properties page there is the output of the program INA, stored in a file with the name of the analyzed network and extension INA.

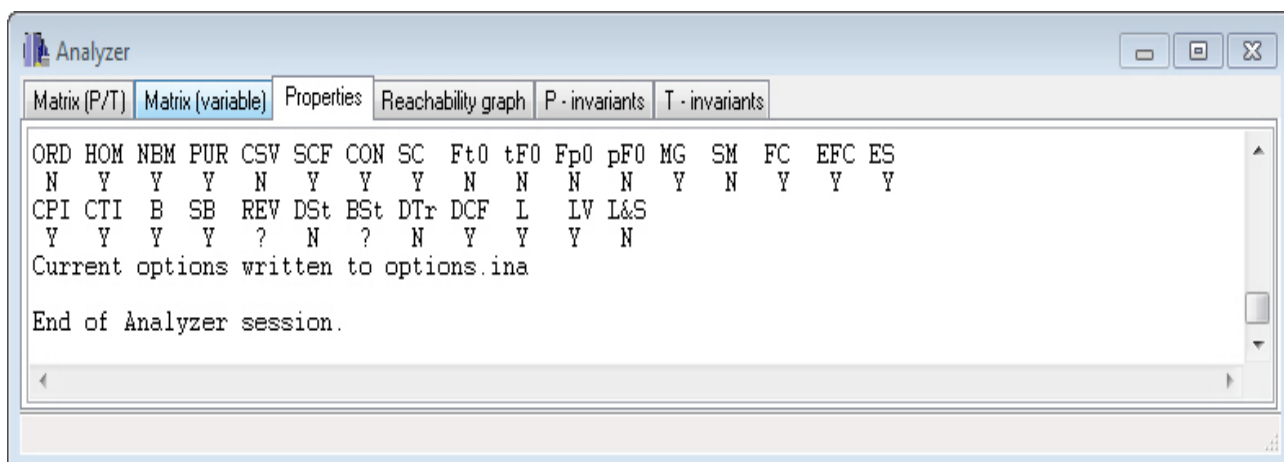


```

Analyzer
Matrix (P/T) Matrix (variable) Properties Reachability graph P-invariants T-invariants

Integrated Net Analyzer [v2.2p6-Mar 23 2001-win32] session report:
Current net options are:
  token type: black          (for Place/Transition nets)
  time option: no times
  firing rule: normal with capacities
  priorities : not to be used
  strategy   : single transitions
  line length: 255

Net read from 7_en.pnt
Information on elementary structural properties:
Current name options are:
  transition names to be written
  place names to be written
The net is statically conflict-free.
The net is dynamically conflict-free.
The net is pure.
The net is not ordinary.
The net is not conservative.
The net is not subconservative.
The net is not a state machine.
The net is free choice.
The net is extended free choice.
  
```



```

Analyzer
Matrix (P/T) Matrix (variable) Properties Reachability graph P-invariants T-invariants

ORD HOM NBM PUR CSV SCF CON SC Ft0 tF0 Fp0 pF0 MG SM FC EFC ES
N Y Y Y N Y Y Y N N N N Y N Y Y Y
CPI CTI B SB REV DSt BSt DTr DCF L LV L&S
Y Y Y Y ? N ? N Y Y Y N
Current options written to options.ina

End of Analyzer session.
  
```

To see all properties of the analyzed Petri net, which could be studied, scroll to the end of the properties report.

The first line of the above statements describes the elementary properties of the Petri net.

ORD - ordinary - A net is said to be ordinary, if the multiplicity of every arc equals one.

A coloured net is ordinary, if its unfolded net is ordinary.

HOM – homogenous - A net is said to be homogenous, if for any place p , all arcs starting at p have the same multiplicity.

NBM- non-blocking multiplicity - A net has non-blocking multiplicity, if for each place p , the minimum of multiplicities of the arcs ending at p is not less than the maximum of multiplicities of the arcs starting at p .

PUR - pure - INA checks, whether there is a transition in the current net, for which a pre-place is also a post-place.

In this case, the net is not pure, i.e. not loop-free. Such nets are not live under the safe firing rule.

CSV - conservative - A net is said to be conservative, if all transitions add exactly as many tokens to their post-places

as they subtract from their pre-places. In a conservative net, the total number of tokens is thus not altered by firing any transition.

Therefore, the amount of tokens is an invariant.

SCF - static conflict free - If two transitions have a common pre-place, they are in a static conflict about the tokens on this pre-place.

Then, the net is not static conflict free.

CON - connected - A net is said to be connected, if for each node in the net, there exists an undirected path to every other node,

The direction of the arcs is thus ignored in the corresponding investigation.

SC - strongly connected - If a net is connected, it is checked whether each node also has a directed path to every other node,

i.e. the direction of the arcs is also considered.

Ft0 - transition without pre-place - A net has Ft0-transitions, if there are transitions without a pre-place; Ft=0

tF0 - transition without post-place - A net has tF0-transitions, if there are transitions without a post-place; tF=0

Fp0 - place without pre-transition - A net has Fp0-places, if there are places without pre-transitions; Fp=0

pF0 - place without post-transition - A net has pF0-places, if there are places without post-transitions; pF=0

MG - marked graph - A net is a synchronisation (or marked) graph, if every place has exactly one pre-transition and one post-transition.

Here, arc multiplicities are ignored

SM - state machine - A net is a state machine, if every transition has exactly one pre-place and one post-place.

Here, arc multiplicities are ignored.

FC - free choice - A net has free choice, if every shared place is the only pre-place of its post-transitions.

EFC - extended free choice - A net has extended free choice, if the post-transitions of shared places have the same pre-places.

ES - extended simple - A net is extended simple, if the following holds:

If two places have a common post-transition, then for one of them, its post-transitions are also post-transitions of the other place; i.e., one of the two places can also have other post-transitions.

Key features are listed in the above statement in the second row.

CPI - covered by place invariants - A net is covered by place invariants, if there exists a P-invariant which assigns a positive value to each place

CTI - covered by transition invariants - A net is covered by transition invariants, if there exists a T-invariant which assigns a positive value to each transition

B - bounded - A net is bounded, if there is a number k such that, in any reachable marking, there are never more than k tokens on a place.

SB - structurally bounded - A net is structurally bounded, if it is bounded in every initial marking.

REV - reversible - A net is reversible, if the initial state can be reached from every reachable state.

This property is not analyzed by the application.

DSt - dead state reachable - A dead state is reachable, if a state is reachable in which no transition can fire any more.

BSt - bad predicate - If a state satisfies a so-called "bad" predicate, it is not further developed when computing a state graph.

DTr - dead transition at initial marking - This attribute indicates whether the net has dead transitions in the initial marking, i.e. facts.

DCF - dynamically conflict free - A net is said to be dynamically conflict free, if no state is reachable

in which two transitions are enabled and one of them can be disabled by firing the other.

L - live - A net is live, if all its transitions are live in the initial marking, i.e., no state is reachable in which transition is dead.

LV - live when ignoring dead transitions - A net is live when ignoring dead transitions, if all its transitions, which are not already dead in the initial marking, are live.

The transitions thereby ignored can be considered as unspecified facts.

L&S - live and safe - A net is live and safe, if it is live and, in any reachable marking, not more than one token is on a place.

The fourth page of the analyzer dialog contains a reachability graph of the target Petri net.

INA shows the reachability graph as a list of vertices.

Each vertex of the reachability graph contains:

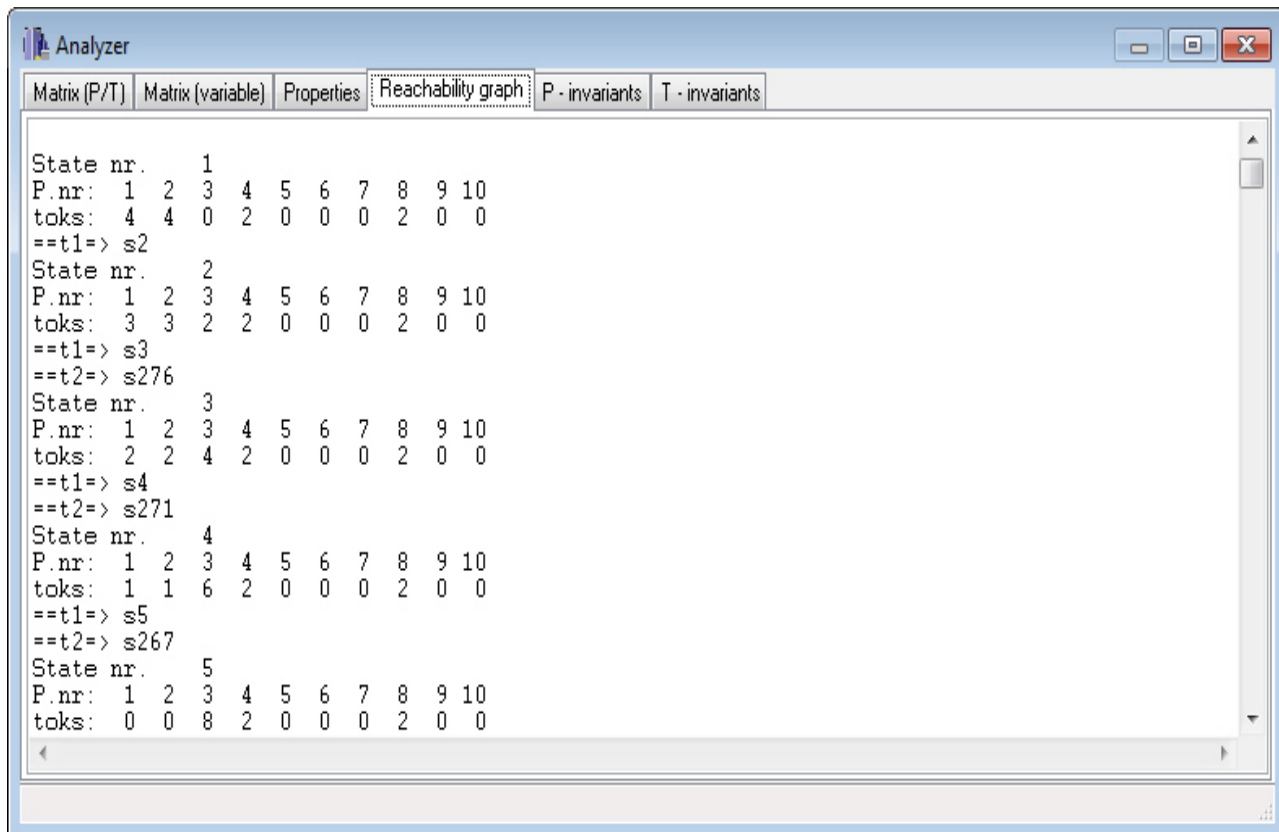
State no. - State number of the reachability graph vertex

P.nr: - a list of numbers present in the analyzed Petri net

toks - number of tokens on the following places of the Petri net

list of transitions that can fire from this state with the conditions that occur after the firing of each of these transition.

Because the analyzed Petri net can be unlimited, the maximum length of a path in the reachability graph is by default set to 1000, which should be sufficient for the analysis of even very complex Petri nets. If, however, it is not enough, you can change it on the "Analyzer" page of the "Settings" dialog window.



The following pages present the calculated P-invariants and T-invariants of the test Petri net.

